

Scientific Article

Foreign Body Reaction in Wrist Arthroplasty Using a Carbon Fiber Reinforced Poly-Ether-Ether-Ketone Articulation: A Secondary Analysis of 11 Cases

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ABSTRACT

Introduction Wrist arthroplasty is a motion-preserving procedure. However, despite improvements in implant design, implant failure remains an issue. The aim of this secondary analysis was to assess failures associated with synovitis and to report histopathological findings in an initial patient cohort ($n = 40$) reported previously.

Materials and Methods Eleven cases of implant failure and synovitis were identified among hemi and total wrist arthroplasties with a carbon fiber reinforced poly-ether-ether-ketone (CFR-PEEK) articulation.

Results Six cases had undergone component exchange/revision; of these, five were revised to a radiocarpal arthrodesis. Pronounced wear of the CFR-PEEK articulating surface was noted. Histopathological examination indicated that CFR-PEEK particles were incorporated by macrophages, but no giant cell reactions could be seen.

Conclusion A high frequency of synovitis warranting reoperation was noted. We recommend caution and close monitoring of CFR-PEEK articulations in the wrist.

Keywords wrist arthroplasty, loosening, arthritis, synovitis, foreign body reaction

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Introduction

Wrist arthritis is a common problem. Nonoperative treatment options include splint immobilization, nonsteroidal anti-inflammatory medication, and selective intra-articular injection of corticosteroids.¹ Surgical treatment options include radioscapulohumeral (RSL) arthrodesis, radiocarpal arthrodesis (RCA), and total wrist arthroplasty (TWA), all of which have their own limitations.² RCA is a well-documented procedure that often results in a pain-free stable wrist but at the expense of wrist motion, limiting function in activities of daily living.^{3,4} RSL arthrodesis can preserve some wrist motion, but nonunion rates of up to 21% as well as progressive arthritis of the midcarpal joint may necessitate additional surgery.⁵ TWA is a motion-preserving procedure. Although implant designs have evolved over recent decades, implant failure remains an issue and short-term outcome is not superior to RCA.^{6–9} Problems related to loosening of the distal component in TWA could potentially be mitigated with a radial wrist hemiarthroplasty (RWHA) design, but results so far have been mixed.^{10–12}

Poly-ether-ether-ketone (PEEK) has sometimes been used in orthopaedic implants. Experimental data on possible biological reactions associated with PEEK wear particles suggest that the wear debris of PEEK is comparable to that of ultra-high molecular weight polyethylene (UHMWPE) in its biological activity.¹³ Several types of implants, including those for knee and wrist arthroplasty, utilize PEEK either as a primary bearing surface or as a structural component, often in combination with other materials such as metal.¹⁴ Some findings indicate issues regarding PEEK's biocompatibility and wear behavior in the human body.¹⁵ Moreover, wear-related problems, pseudotumor formation, and osteolysis have all been reported.^{16,17} In TWA, carbon fiber reinforced PEEK (CFR-PEEK) has been proposed as an alternative to metal-on-metal articulations. While short-term analyses indicate minimal damage and self-polishing of the articulating surfaces, some findings indicate rim damage due to component impingement, suggesting a need for further long-term follow-up and monitoring.^{15,18}

In two previous studies, we reported on a new modular TWA and RWHA design using a CFR-PEEK articulating surface.^{19,20}

The aim of this secondary analysis was to assess revisions related to synovitis/component wear and to analyze histopathological findings in these two series of patients.

Materials and Methods

This single-center study was conducted as a secondary analysis of two previous studies. It was approved by the Swedish Ethical Review Authority (reference: 2025-02983-02) and followed the tenets of the World Medical Association Declaration of Helsinki. The study took place at Örebro University Hospital, a tertiary referral center in Sweden. All wrist arthroplasties with the new TWA and RWHA were performed by one senior surgeon, who also designed the implants in collaboration with the manufacturer (Trimed TWA, Trimed Inc., Santa Clarita, CA). The implant is not commercially available. Every participant provided written informed consent. Indications for surgery were wrist arthritis with unsustainable pain after nonoperative treatment. Involvement of the lunate fossa excluded proximal row carpectomy as a surgical treatment option.²¹

The new TWAs and RWHAs were used in two series of 20 patients each: the first series received a RWHA designed with a CFR-PEEK articulation and tantalum-coated stem, and the other received a TWA with CFR-PEEK with hydroxyapatite coating of the bone-to-metal interface. In all cases, the radial articulation was made of CFR-PEEK with an elastic modulus similar to cortical bone. The radial stem had a press-fit design with a central core of stainless steel, whereas the RWHA had a porous coating of titanium and a thin outer layer of tantalum. The radial component had wing-like expansions, intended to increase rotational stability. The carpal component screws had locking options. The CFR-PEEK liner was modular and attached to the radial component with a snap-fit mechanism, making conversion of the RWHA to a TWA possible without exchange of the radial component (Figs. 1 and 2). The TWA implant has previously been biomechanically validated in a cadaveric study.²² The CFR-PEEK liner for the RWHA came in two different component sizes, designed for the options of preservation or removal of the proximal carpal row. The distal part of the radial stem, holding

the CFR-PEEK liner, had a flat vertical surface that rested directly on the cortical bone, potentially reducing the risk of stress shielding and reducing wear on both sides of the implant. Details of the surgical approach and preparation have been reported previously.^{19,20}

A CFR-PEEK-related revision was defined as a reoperation that resulted in exchange of the CFR-PEEK component or revision to another arthroplasty or to RCA due to chronic synovitis and/or PEEK failure. In some cases, biopsies and intraoperative photos were taken during reoperation. A total of 11 patients with massive synovitis were identified; 8 of them had been reoperated due to problems with synovitis and CFR-PEEK wear, and another 3 patients (1 RWHA and 2 TWA) were planned for revision surgery due to the same problems.

Clinical Evaluation

The following outcome measures were recorded preoperatively, at 1 and 2 years postoperatively, and at the latest follow-up (5 years postoperatively). Wrist pain at rest and during activity was measured with a visual analog scale (VAS) ranging from 0 (no pain) to 10 (the worst pain imaginable). Hand grip strength was recorded in kilograms using a hydraulic hand dynamometer (North Coast Medical Inc., Morgan Hill, CA). The mean value of three measurements was calculated. Wrist range of motion (ROM), including flexion, extension, radial deviation, ulnar deviation, pronation, and supination, was assessed using a goniometer. All measurements were performed according to current guidelines from the Swedish National Quality Registry for Hand Surgery.²³

Patient-reported outcome measures were assessed using Swedish translations of the performance and satisfaction components of the Canadian Occupational Performance Measure (COPM) and the Disabilities of the Arm, Shoulder and Hand (DASH) score. The COPM has two variables (performance and satisfaction) and is an outcome measure designed to assess changes in self-perceived occupational performance over time. The patient identifies activities of daily living in areas of productivity, leisure, and self-care through a semi-structured interview,



Fig. 1 (A) Postoperative radial wrist hemiarthroplasty with lunate impingement; (B) 1 year postoperatively, after proximal row carpectomy; (C) postoperative total wrist arthroplasty; (D) 1 year postoperatively.

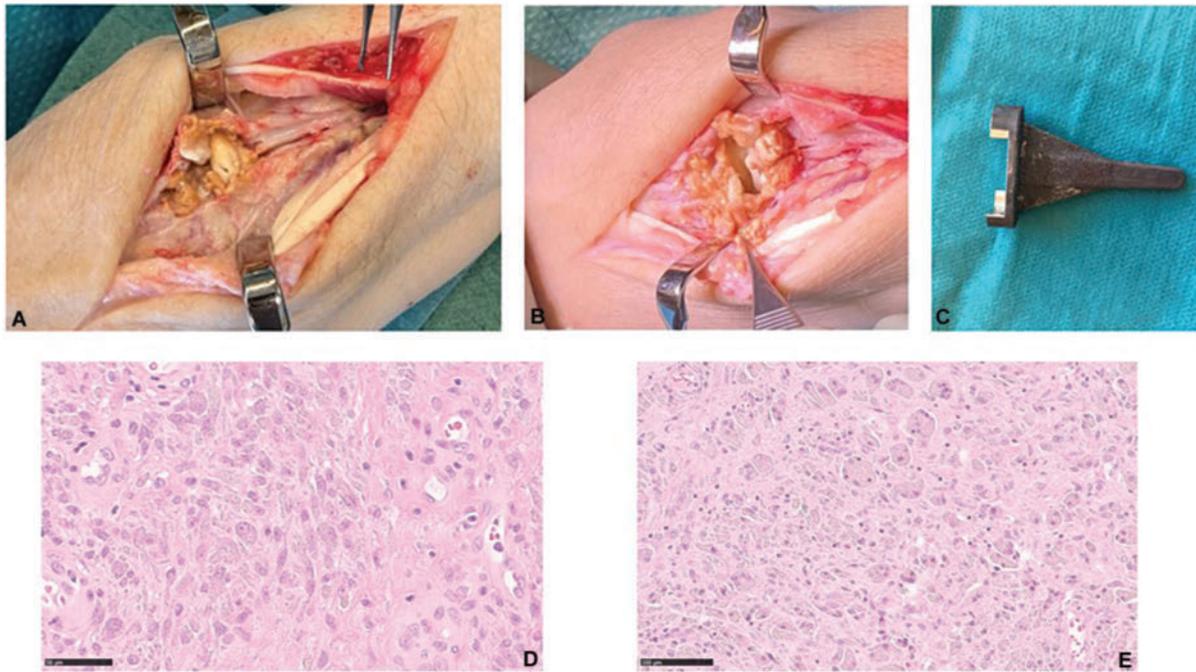


Fig. 2 (A–C) Intraoperative photos of radial wrist hemiarthroplasty extraction; CFR-PEEK particles are incorporated into histiocytes (D–E). CFR-PEEK, carbon fiber reinforced poly-ether-ether-ketone.

and then rates their level of performance and satisfaction with performance on a scale ranging from 1 to 10.²⁴

Histological Examination

The intraoperative tissue samples were fixed with 4% paraformaldehyde, embedded in paraffin, sliced into 4- μ m-thick sections, and stained with hematoxylin–eosin in a standard procedure. CD68 (clone KP1, Agilent, Santa Clara, CA) immunostaining was performed according to a pre-set protocol on a Dako Omnis immunostainer equipped with the Envision detection system (polymer-based HRP/DAB kit).

Results

Of the 40 patients, 11 (6 with a Trimed RWHA, 5 with a Trimed TWA) were identified as having experienced wrist pain in combination with clinical findings of synovitis, resulting in component exchange or revision to RCA. Radiographically, there was no obvious component loosening of the revised cases, but ulnar translation of the carpus was seen in several of the RWHA cases (Fig. 1).

The six reoperated patients from the RWHA series underwent a total of 15 reoperations (Fig. 2A–C). After previous synovectomies, the CFR-PEEK component was exchanged in one patient and revised to RCA in another four patients. In the sixth patient, the RWHA was exchanged for another Trimed TWA with UHMWPE instead of CFR-PEEK. The five reoperated patients from the TWA group underwent a total of 13 reoperations. Two TWAs were revised, one to a Motec TWA (Swemac Ortho-

pedics, Linköping, Sweden) and one to a Trimed TWA with a UHMWPE liner. In one patient, the CFR-PEEK component was exchanged, and another patient was revised to RCA (Table 1). One patient was planned for a revision to a Motec TWA, but at the time of this study had chosen to postpone surgery for personal reasons unrelated to the wrist.

The majority of the complications developed quite rapidly after the index operation (Table 1). At the final follow-up, VAS pain scores at rest had improved but VAS scores during activity were still high, while the mean DASH score was 32.5 and the mean COPM performance score was 2.8 (Table 2). Due to the low number of patients and the fact that detailed patient-reported outcomes have been reported in previous publications, no analyses for statistical significance were undertaken.

Histopathology

In patient A from the RWHA series, a typical “wear-and-tear type” histological reaction was seen, characterized by birefringent particles phagocytosed by macrophages. CRF-PEEK was associated with a florid histiocytic response, but notably without giant cells. The histiocytes contained fine, granular material consistent with particle ingestion. The synovial tissue also exhibited marked edema (Fig. 2D, E).

In patient B from the TWA series, who had previously undergone revision from a CFR-PEEK liner to UHMWPE, a florid giant cell reaction was observed, highlighted by CD68 immunostaining (Fig. 3A–E). Mononuclear macrophages were scarce. The multinucleated giant cells were seen engulfing granular material, most likely representing UHMWPE wear debris. The loose connective

Table 1 Overview of the patients

Patient	Time to first reoperation (mo)	Time of last follow-up (mo)	Final operation
Patient 1 TWA	9	30	Change to Motec TWA
Patient 2 TWA	4	30	Change to Trimed TWA without CFR-PEEK
Patient 3 TWA	3	13	RCA
Patient 4 TWA	84	84	Component exchange
Patient 5 TWA	8	24	Change to Motec TWA
Patient 1 RWHA	60	Planned for revision	RCA
Patient 2 RWHA	10	10	Component exchange
Patient 3 RWHA	5	14	Change to Trimed TWA without PEEK
Patient 4 RWHA	22	60	RCA
Patient 5 RWHA	24	24	RCA
Patient 6 RWHA	13	13	RCA

Abbreviations: CFR-PEEK, carbon fiber reinforced poly-ether-ether-ketone; RCA, radiocarpal arthrodesis; RWHA, radial wrist hemiarthroplasty; TWA, total wrist arthroplasty.

Note: Patient 4 RWHA corresponds to "patient A" and patient 2 TWA corresponds to "patient B."

Table 2 Mean values of patient-reported outcomes

Outcome	Preoperatively	1 y postoperatively	2 y postoperatively	5 y postoperatively
VAS pain score during activity	8	5	5	8
VAS pain score at rest	8	1	0	4
DASH score	37	10.25	6.6	32.5
COPM performance	7.6	7.4	7.4	2.8
Extension, degrees	0/35	0/30	0/45	0/30
Flexion, degrees	0/50	0/50	0/35	0/30
Ulnar abduction, degrees	0/20	0/20	0/20	0/20
Radial abduction, degrees	0/15	0/10	0/5	0/5
Supination, degrees	0/60	0/60	0/50	0/45
Pronation, degrees	0/80	0/85	0/80	0/70

Abbreviations: COPM, Canadian Occupational Performance Measure; DASH, Disabilities of the Arm, Shoulder and Hand; VAS, visual analog scale.
Note: Cases revised to radiocarpal arthrodesis removed from range of motion measurements.

tissue also indicates edema formation. The black granular material seen most likely represents titanium debris (**Fig. 3D, E**).

Discussion

The results of this secondary analysis show a high number of reoperations due to swelling, edema, pain, and synovitis, but no obvious component loosening. This is noteworthy, as the most common reason for revision in hip arthroplasty is aseptic loosening.²⁵ Both UHMWPE and CFR-PEEK evoke a histiocytic tissue reaction, which is thought to play an important role in aseptic implant loosening. However, there are important differences between UHMWPE and CFR-PEEK-induced reactions. UHMWPE particles are relatively large compared with CFR-PEEK. The smaller CFR-PEEK particles are engulfed by macrophages and do not seem to trigger giant cell formation. Furthermore, the deposition of

UHMWPE fragments is seemingly random, whereas CFR-PEEK is found in a predominantly perivascular localization. The differences in histiocytic responses are likely attributable to differences in cytokine production. The CFR-PEEK biopsy obtained from our series showed the macrophage-rich histopathological picture described previously.²⁶

The RWHA and TWA used in this study had an articulation made of CFR-PEEK, a composite material with a modulus of elasticity close to that of cortical bone. Hypothetically, a joint insert made of CFR-PEEK could reduce wear, reducing the risk of massive synovitis. Concerns have been expressed in recent years about PEEK and the development of side effects and osteolysis. There are indications of cup wear leading to release of PEEK particles into the surrounding synovia, resulting in the formation of a fluid-filled cystic sac with a black lining and diffuse, lymphocyte-dominated inflammation.¹⁶



Fig. 3 (A–C) Intraoperative photos of total wrist arthroplasty with ultra-high molecular weight polyethylene articulation and massive synovitis. (D, E) Biopsies from total wrist arthroplasty with ultra-high molecular weight polyethylene articulation. Giant cell engulfing UHMWPE, loose connective tissue indicating edema formation, black granular material, a foreign body reaction to metal particles, with both macrophages and occasional giant cells participating in phagocytosis. The image is consistent with metallosis tissue following implant placement. UHMWPE, ultra-high molecular weight polyethylene.

CFR-PEEK has been studied in hip and knee arthroplasties, with mixed results.^{26,27} Paulus et al. described a histopathological analysis of the effects of PEEK wear particles on synovial tissue.²⁸ The results showed that UHMWPE and PEEK exhibit different scattering behavior in human synovial tissue. In addition, CFR-PEEK particles were seen as conglomerates and could only be found adjacent to vessels. PEEK particles behave differently from conventional UHMWPE wear particles. Studies on knee arthroplasties show that UHMWPE particles are scattered throughout the tissue and sometimes trigger giant cell responses, whereas CFR-PEEK particles tend to cluster near blood vessels and are taken up primarily by macrophages without giant cell involvement. This unique distribution and the lack of a significant inflammatory response could support the potential of PEEK for reduced cytotoxicity, although its impact on implant longevity in TWA remains uncertain.¹⁵

In hand and wrist surgery, osteolysis has been observed in some cases with PEEK suture anchors, with a measurable enlargement of the bone tunnel.¹⁷ In addition, adverse reactions such as lymphocyte-dominated inflammation have been noted when PEEK wear particles accumulate, especially under nonweight-bearing conditions. These reactions are distinct from the granulomatous reactions observed with polyethylene and may lead to osteolysis or implant loosening over time.

Although PEEK is a promising implant material due to its biocompatibility and lower cytotoxicity, its wear-related effects, especially in nonweight-bearing joints, need to be further investigated to fully understand its suitability for long-term use in orthopaedic applications. In a study of seven cases, Joyce et al.

noted no worrisome problems with the bearing surfaces of a Motec TWA implant using CFR-PEEK.¹⁸ In addition, a study of knee arthroplasties using PEEK as the bearing material described no major PEEK-related problems.²⁶

Several cases in the RWHA series showed ulnar translation of the carpal bone, requiring reoperation.²⁰ The extent to which ulnar translation contributed to implant wear, edema, and synovitis is difficult to quantify. Eccentric loading may have contributed to the CRF-PEEK wear observed in these patients during reoperation. However, this does not explain why 5 of 20 patients who underwent TWA with a CFR-PEEK joint had similar issues with edema, pain, and synovitis.¹⁹ No ulnar translation of the carpus was noted in the TWA group, but there was considerable wear of the CRF-PEEK. This was likely related to the implant design, the CRF-PEEK itself, or a combination of both factors. The black granular material noted in the RWHA case is likely titanium debris from the surface of the radial component.

VAS pain values during activity were high in our series. The wrist flexion and extension measurements reflect the fact that 5 of the 11 patients underwent an RCA. The issue of limited wrist extension may also be related to suboptimal implant alignment, as a recent study found an association between TWA component alignment and wrist ROM.²⁹ Friction may be another reason for limited ROM. An experimental study demonstrated that the friction factors produced by metal-on-CFR PEEK unicondylar knee joints are considerably higher than those found for conventional metal-on-polyethylene knees. These experimental findings could support the hypothesis of higher friction in a metal-on-CFR

PEEK articulation in comparison to a metal-on-polyethylene articulation.^{30,31}

COPM scores had improved substantially at the last follow-up, but DASH scores were high, indicating a poor hand function. Franko et al. have demonstrated that functional disability of the wrist correlates with decreased wrist motion.³² Drawbacks of using the DASH score in studying postoperative outcomes after TWA have been reported previously.^{33,34} In contrast, the COPM score is individualized, allowing for a more specific focus on wrist problems, and is a sensitive tool for capturing clinically important improvement after hand surgery.³⁵ There was inevitably some ambiguity in the case inclusion criteria, and all cases had not yet undergone reoperation. Another limitation is that histological examination was only done in two patients, but the clinical and intraoperative findings were similar. In addition, there was no control group.

Finally, it must be pointed out that our observations do not allow us to draw a conclusion as to whether a UHMWPE coating or a PEEK or CRF-PEEK coating is more durable in vivo. Further direct comparative studies could provide additional information on this.

Given the high frequency of edema, pain, swelling, and synovitis resulting in a high frequency of reoperation, we recommend caution and close monitoring of CFR-PEEK articulations in the wrist.

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Statements and Additional Information

Conflict of Interest The authors declare that they have no conflict of interest.

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References

- 1 Weiss KE, Rodner CM. Osteoarthritis of the wrist. *J Hand Surg Am* 2007;32(05):725–746
- 2 Weiss AP, Akelman E. Total wrist replacement. *Med Health R I* 2012;95(04):117–119
- 3 Rauhaniemi J, Tiusanen H, Sipola E. Total wrist fusion: a study of 115 patients. *J Hand Surg [Br]* 2005;30(02):217–219
- 4 Toma CD, Machacek P, Bitzan P, Assadian O, Trieb K, Wanivenhaus A. Fusion of the wrist in rheumatoid arthritis: a clinical and functional evaluation of two surgical techniques. *J Bone Joint Surg Br* 2007;89(12):1620–1626
- 5 Zelenski NA, Trentadue TP, Moran SL, Rizzo M. Radiographic and clinical outcomes of radioscapholunate arthrodesis in patients with inflammatory and posttraumatic arthritis. *Hand (N Y)* 2023;18(2_suppl, suppl):1025–1105
- 6 Krukhaug Y, Lie SA, Havelin LI, Furnes O, Hove LM. Results of 189 wrist replacements. A report from the Norwegian Arthroplasty Register. *Acta Orthop* 2011;82(04):405–409
- 7 Reigstad O, Holm-Glad T, Korslund J, Grimsgaard C, Thorkildsen R, Røkkum M. 15-20 year follow-up after wrist arthroplasty surgery - revisiting the development and introduction of a new prototype concept for total wrist arthroplasty. *J Hand Surg Asian Pac Vol* 2022;27(06):945–951
- 8 Ward CM, Kuhl T, Adams BD. Five to ten-year outcomes of the Universal total wrist arthroplasty in patients with rheumatoid arthritis. *J Bone Joint Surg Am* 2011;93(10):914–919
- 9 Clementson M, Larsson S, Abramo A, Brogren E. Clinical and patient-reported outcomes after total wrist arthroplasty and total wrist fusion: a prospective cohort study with 2-year follow-up. *JBJS Open Access* 2024;9(01):e23.00081
- 10 Gaspar MP, Lou J, Kane PM, Jacoby SM, Osterman AL, Culp RW. Complications following partial and total wrist arthroplasty: a single-center retrospective review. *J Hand Surg Am* 2016;41(01):47–53.e4
- 11 Culp RW, Bachoura A, Gelman SE, Jacoby SM. Proximal row carpectomy combined with wrist hemiarthroplasty. *J Wrist Surg* 2012;1(01):39–46
- 12 Anneberg M, Packer G, Crisco JJ, Wolfe S. Four-year outcomes of midcarpal hemiarthroplasty for wrist arthritis. *J Hand Surg Am* 2017;42(11):894–903
- 13 Utzschneider S, Becker F, Grupp TM, et al. Inflammatory response against different carbon fiber-reinforced PEEK wear particles compared with UHMWPE in vivo. *Acta Biomater* 2010;6(11):4296–4304
- 14 Koh YG, Park KM, Lee JA, Nam JH, Lee HY, Kang KT. Total knee arthroplasty application of polyetheretherketone and carbon-fiber-reinforced polyetheretherketone: a review. *Mater Sci Eng C* 2019;100:70–81
- 15 Redfern JAI, Mehta N, Farnebo S, et al. Complication rates and modes of short and medium-term failure in Motec total wrist arthroplasty: an international cohort study. *J Hand Surg Eur Vol* 2024;49(01):27–33
- 16 Karjalainen T, Pamilo K, Reito A. Implant failure after Motec wrist joint prosthesis due to failure of ball and socket-type articulation-two patients with adverse reaction to metal debris and polyether ether ketone. *J Hand Surg Am* 2018;43(11):1044.e1–1044.e4
- 17 Chen JS, Paksima N, Rocks MC, Lin CC, Catalano LW III. Osteolysis following the use of polyetheretherketone suture anchors in hand and wrist surgery: a preliminary study. *J Hand Surg Am* 2023
- 18 Joyce TJ, Kandemir G, Warwick D, Brown DJ. Investigation of the short-term in vivo performance of metal-on-carbon fibre reinforced poly ether ether ketone Motec wrists: an explant analysis. *J Hand Surg Eur Vol* 2025;50(01):114–119
- 19 Reiser D, Fischer P, Pettersson K, Wretenberg P, Sagerfors M. Total wrist arthroplasty with a new design: 20 cases with 8-year follow-up. *J Hand Surg Am* 2025;50(03):377.e1–377.e8
- 20 Reiser D, Sagerfors M, Wretenberg P, Pettersson K, Fischer P. Clinical, radiographic, and patient-perceived outcome after radial hemi-wrist arthroplasty with a new implant: 20 cases with 5-year follow-up. *Hand (N Y)* 2023;19(05):742–750
- 21 Logan JS, Warwick D. The treatment of arthritis of the wrist. *Bone Joint J* 2015;97-B(10):1303–1308
- 22 Hooke AW, Pettersson K, Sagerfors M, An KN, Rizzo M. An anatomic and kinematic analysis of a new total wrist arthroplasty design. *J Wrist Surg* 2015;4(02):121–127
- 23 Nationell Manual. Manual för rörelse- och styrkemätning av armbåge, underarm och hand Version 1. 2016. Accessed June 30, 2025 at: <https://hakir.se/about-hakir/>
- 24 Wolff AL, Patel Y, Zusstone E, Wolfe SW. Self-identified functional limitations improve in patients with degenerative wrist arthritis after surgery. *J Hand Ther* 2020;33(04):540–546
- 25 Ulrich SD, Seyler TM, Bennett D, et al. Total hip arthroplasties: what are the reasons for revision? *Int Orthop* 2008;32(05):597–604
- 26 Vertesich K, Staats K, Böhler C, Koza R, Lass R, Giurea A. Long term results of a rotating hinge total knee prosthesis with carbon-fiber reinforced poly-ether-ether-ketone (CFR-PEEK) as bearing material. *Front Bioeng Biotechnol* 2022;10:845859
- 27 Heijens LJ, Schotanus MG, Verburg AD, van Haaren EH. Disappointing long-term outcome of THA with carbon-fiber-reinforced poly-ether-ether-ketone (CFR-PEEK) as acetabular insert liner: a prospective study with a mean follow-up of 14.3 years. *Hip Int* 2021;31(06):735–742

- 28 Paulus AC, Haßelt S, Jansson V, et al. Histopathological analysis of PEEK wear particle effects on the synovial tissue of patients. *BioMed Res Int* 2016;2016:2198914
- 29 Akhbari B, Shah KN, Morton AM, et al. Total wrist arthroplasty alignment and its potential association with clinical outcomes. *J Wrist Surg* 2021;10(04):308–315
- 30 Scholes SC, Unsworth A. Wear studies on the likely performance of CFR-PEEK/-CoCrMo for use as artificial joint bearing materials. *J Mater Sci Mater Med* 2009;20(01):163–170
- 31 Ash HE, Scholes SC, Unsworth A, Jones E. The effect of bone cement particles on the friction of polyethylene and polyurethane knee bearings. *Phys Med Biol* 2004;49(15):3413–3425
- 32 Franko OI, Zurakowski D, Day CS. Functional disability of the wrist: direct correlation with decreased wrist motion. *J Hand Surg Am* 2008;33(04):485–492
- 33 Murphy DM, Khoury JG, Imbriglia JE, Adams BD. Comparison of arthroplasty and arthrodesis for the rheumatoid wrist. *J Hand Surg Am* 2003;28(04):570–576
- 34 Nydick JA, Watt JF, Garcia MJ, Williams BD, Hess AV. Clinical outcomes of arthrodesis and arthroplasty for the treatment of posttraumatic wrist arthritis. *J Hand Surg Am* 2013;38(05):899–903
- 35 Malcus Johnsson P, Sandqvist G, Stureson AL, et al. Individualized outcome measures of daily activities are sensitive tools for evaluating hand surgery in rheumatic diseases. *Rheumatology (Oxford)* 2012;51(12):2246–2251